(12) UK Patent Application (19) GB (11) 2 180 342 (13) A

(43) Application published 25 Mar 1987

(21) Application No 8520338

(22) Date of filing 14 Aug 1985

(71) Applicant
Alcom Limited

(Incorporated in United Kingdom)

299a Edgware Road, London W2 1BB

(72) Inventor
Christopher John Faisal Terry

(74) Agent and/or Address for Service
Haseltine Lake & Co,
Hazlitt House, 28 Southampton Buildings, Chancery Lane, London WC2A 1AT

(51) INT CL⁴
G08C 21/00

(52) Domestic classification (Edition I):
G1N 1A3B 3S10 3S11 3S1A 3S2 3V5 4C 7H2 7S AQA

(56) Documents cited
GB A 2138567 US 4121049 US 3657475
GB A 2125971

(58) Field of search
G1N
H4T
Selected US specifications from IPC sub-class G08C

(54) Pressure sensitive device

(57) This device is a touch screen or touch keyboard having a surface (1) and using force or pressure sensors (T1–T4) to measure force applied by the finger to the surface. Calculation of the position of the finger at areas not directly overlying any of the sensors is carried out on the basis of the data from the sensors. Three or four such sensors may be used. In addition to those sensors, there is a further sensor (T5) to which a weight (4) is attached to measure the forces applied to the screen or keyboard as a whole to compensate in the calculations for movements (change of orientation) of the screen or keyboard.

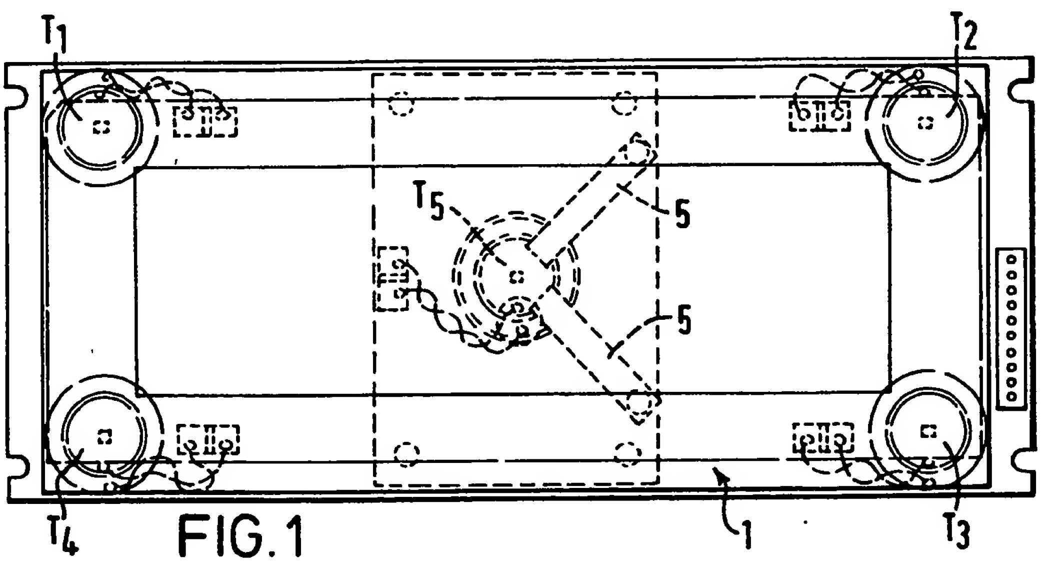

FIG.1

GB 2 180 342 A

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

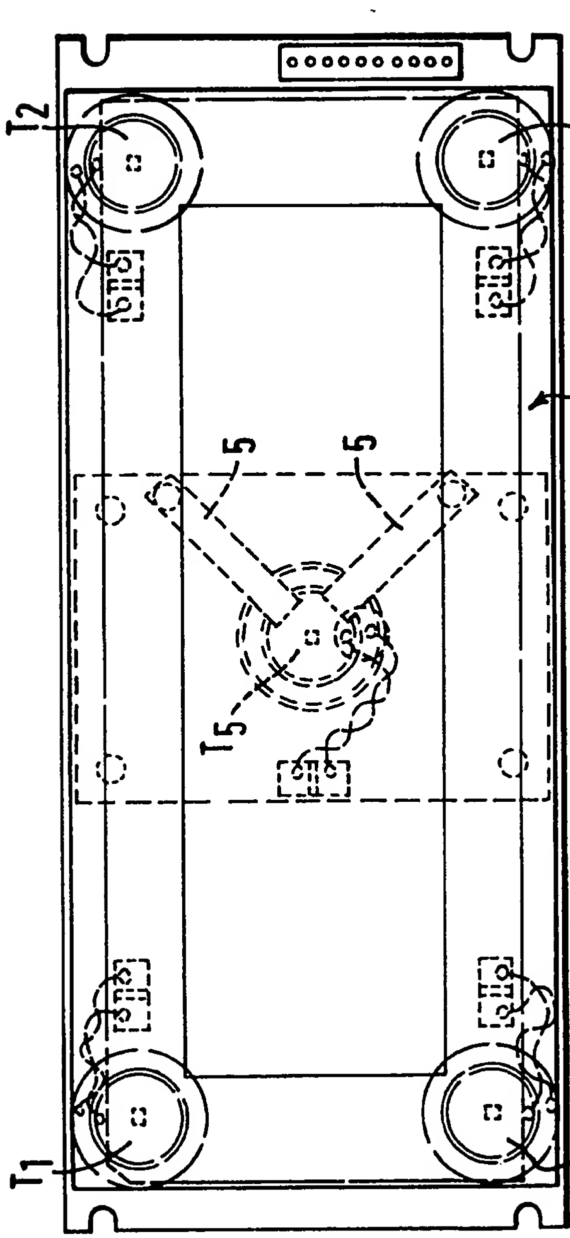

FIG.1

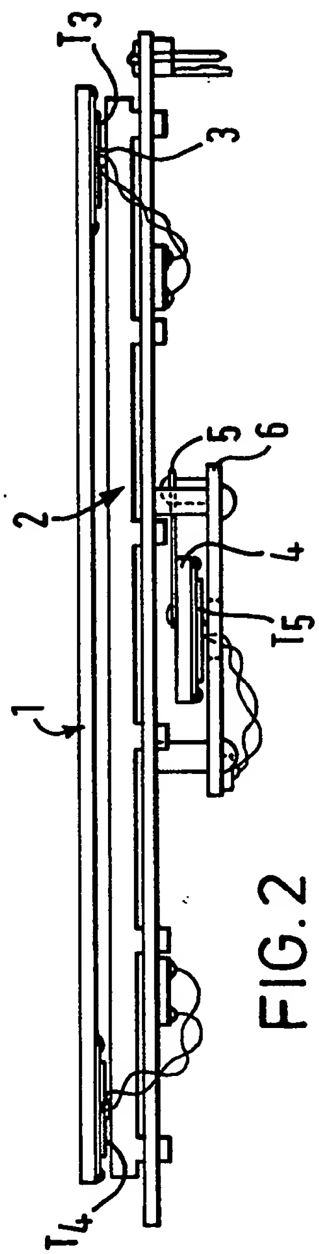

FIG.2

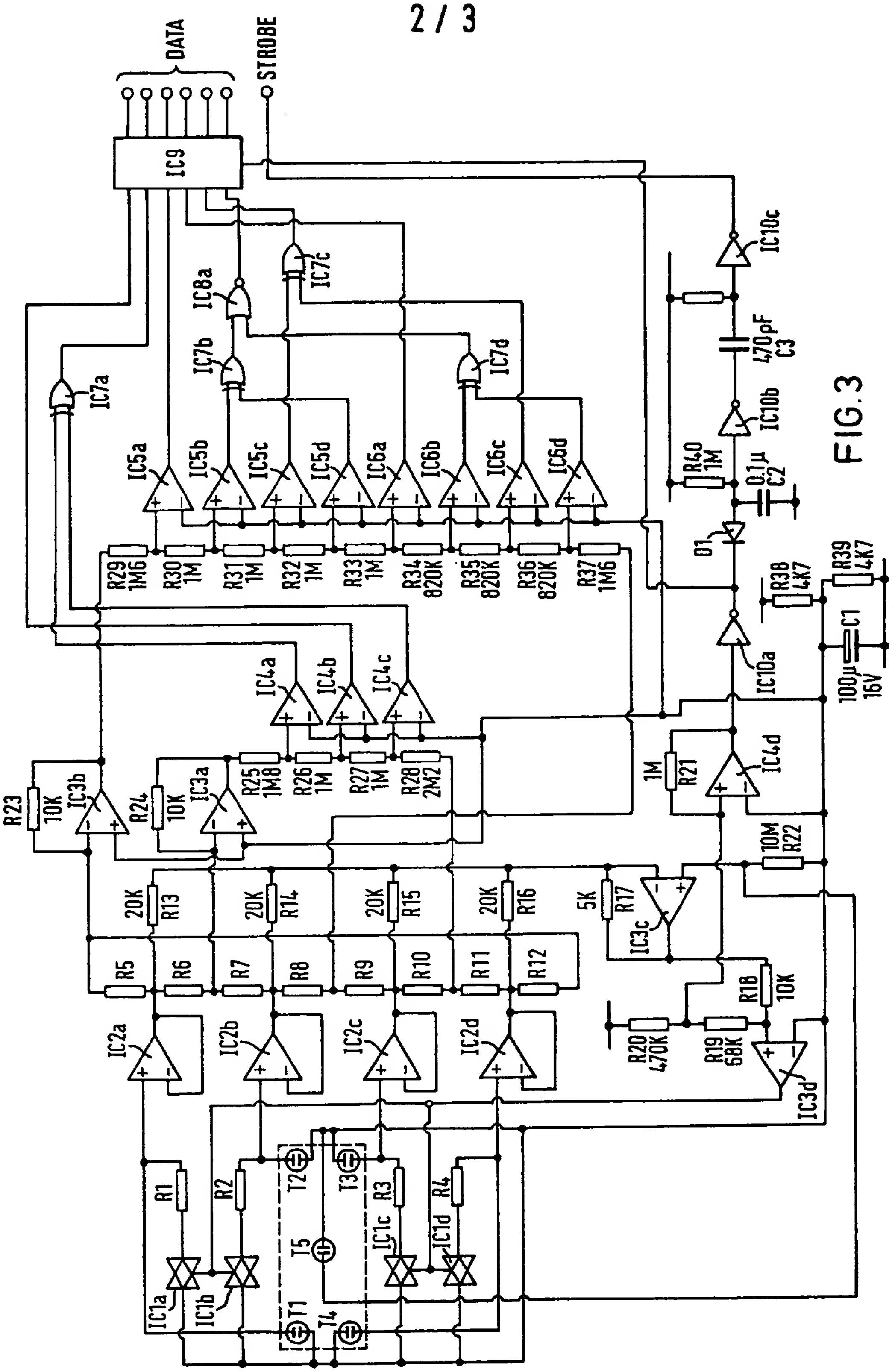
DATA
STROBE
IC9
IC7a
IC7b
IC7c
IC7d
IC8a
IC5a
IC5b
IC5c
IC5d
IC6a
IC6b
IC6c
IC6d
R29 1M6
R30 1M
R31 1M
R32 1M
R33 1M
R34 820K
R35 820K
R36 820K
R37 1M6
IC4a
IC4b
IC4c
IC4d
R25 1M8
R26 1M
R27 1M
R28 2M2
R21 1M
R23 10K
R24 10K
IC3a
IC3b
IC3c
IC3d
R13 20K
R14 20K
R15 20K
R16 20K
R17 5K
R22 10M
R5
R6
R7
R8
R9
R10
R11
R12
R18 10K
R19 68K
R20 470K
IC2a
IC2b
IC2c
IC2d
R1
R2
R3
R4
T1
T2
T3
T4
T5
IC1a
IC1b
IC1c
IC1d
IC10a
IC10b
IC10c
D1
R38 4K7
R39 4K7
C1 100µ 16V
R40 1M
C2 0.1µ
C3 470pF

FIG. 3

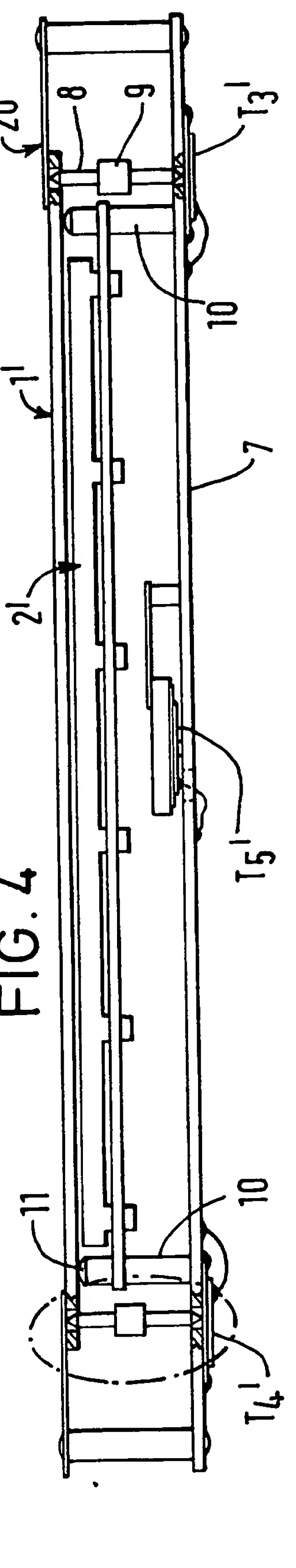

FIG. 4

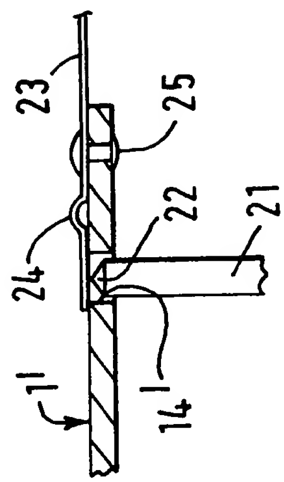

FIG. 6

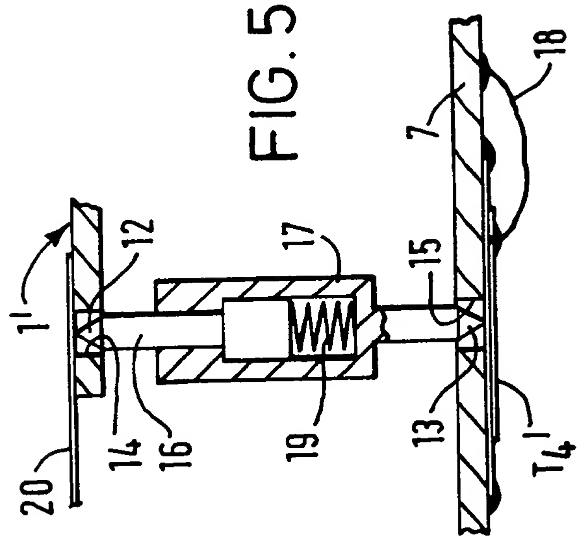

FIG. 5

SPECIFICATION

Pressure sensitive device

The present invention relates to a pressure sensitive device and to a location sensing apparatus incorporating the device.

It is sometimes undesirable or impossible to use a conventional keyboard employing mechanical switches as an input device for microprocessor controlled equipment. Other input devices have been devised, including so-called "touch screens". There are currently on the market various microprocessor based systems which have a "touch screen" as a built in feature. There are also kits available for fitting standard systems with touch screens. In most cases the touch screen is located in front of a CRT display.

The addition of a touch screen enables a conventional monitor display to be used to input data to a microprocessor. This is done by displaying on the monitor display a plurality of different regions or "keys". The "touch screens" can sense which of those regions is being indicated by a user to impart that information to the microprocessor. The usefulness of these touch screens is that the regions displayed can be positioned, labelled and changed in size automatically by the microprocessor software. Such an arrangement allows a high degree of flexibility in the positioning and labelling of keys used to control a computer program. It is particularly useful when the program contains a number of operating modes which may be entered into. The positioning and labelling of keys can be chosen at will for each mode of operation.

However, heretofore touch screens have employed various techniques each of which leave much to be desired by way of transparency, accuracy, power consumption, durability or the complexity and cost of implementation. Examples of these techniques include the interruption of light beams parallel to the display surface or physi-cal contact between conductive films placed in front of the display.

The approach using light beams suffers from the disadvantages of high cost and complexity, high power consumption, possible interference from extraneous sources of radiation and excessive distance between the sensitive surface and parts of the display surface if the latter is not flat, as in the majority of CRT displays.

The approaches based on conductive films suffer from the disadvantages of poor transparency and unreliability. The transparency is compromised by the presence of two layers of metallisation, four or six reflective boundaries, and, in some cases, a matrix of small irregularities used for spacing purposes. As the front film must be flexible, it must be thin, and is therefore vulnerable to damage from sharp objects such as fingernails. It may also transmit lateral displacement giving rise to wear of the conductive surfaces which, of necessity, must be extremely thin.

Although it would theoretically be possible to use such existing touch screens with LCD displays, this is not practicable in low cost portable equipment, owing to high power consumption; poor transparency, high cost or a combination of these drawbacks.

According to one aspect of the present invention, there is provided a pressure sensitive device comprising a member coupled to a plurality of transducers arranged to sense pressure applied to the member and disposed in spaced apart relationship such that when pressure is applied to the member at any one of a plurality of locations on the member and spaced from all the transducers, the pressure sensed by each transducer is dependent on the location at which said pressure is applied to the member, each transducer being capable of outputting a signal in dependence on the pressure sensed thereby.

According to another aspect of the present invention there is provided a location sensing apparatus having a device as defined in the preceding paragraph and means for processing said signals to provide signals representing coordinates of the location at which said pressure is applied.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a plan view of a pressure sensitive device;

Figure 2 is a side view of the device of Figure 1; and

Figure 3 is a circuit diagram of one form of processing arrangement.

Figure 4 shows an alternative form of pressure sensitive device;

Figure 5 is an enlarged view of the encircled portion of Figure 4 showing one form of stress relief mechanism; and

Figure 6 is a diagram of an alternative stress relief mechanism.

The principle of operation of the apparatus involves the measurement of forces by means of transducers which form part of the supporting structure of a surface.

Suitable transducers are the type 7BB-20-6A0 manufactured by Murata Mfg. Co.Ltd. Kyoto, Japan.

Although such transducers are often used to convert electrical energy into vibrational energy, they also exhibit the property of converting pressure into electrical energy. More accurately, the transducers sense a force applied thereto, which is provided by the pressure applied over the area of the element (finger or the like) used to apply the pressure. This property can be used to good effect by attaching the peripheries of the transducers to

a surface and mechanically coupling their centres to the supporting structure.

Figure 1 shows a pressure sensitive apparatus having a surface 1 provided by a rectangular piece of glass with four piezoelectric transducers T_1-T_4 attached by their periphery to the corner regions of the glass. The centres of the transducers T_1-T_4 are, in turn, attached to the metal frame of a dot matrix LCD display 2 such as the type LM200 manufactured by Hitachi Ltd., Tokyo, Japan. Spacers 3 are provided to ensure that force is applied to the transducers at their centres, since the surface of the transducer is flat, and also to insulate the metallised surface of the transducer from the metal frame of the display. The other side of the transducer is slightly concave, so no spacing is required at its edge. Any suitable transparent material could be used in place of glass. A keyboard is displayed by the display 2 so as to provide for the glass 1 a plurality of "virtual" keys or locations. By altering the display, positioning and labelling of the "virtual" keys can be effected as desired.

Alternatively, the transducers could be supported at their peripheries and mechanically coupled to the surface 1 at their centres, either directly or by means of a linkage structure.

A fifth transducer T_5 is attached by its edge to the underside of a steel disc 4 of a mass equal to one eighth of the mass of the glass. This is supported by two orthogonal phosphor bronze strips 5 fixed at their ends to a board 6 attached to the back of the display 2. The transducer T_5 is attached to the board 6 at its centre.

The five transducers T_1-T_5 are electrically connected to a terminal strip (not shown) mounted on the back of the display 2 using screened leads where appropriate to avoid possible electrostatic or radio frequency interference.

A power supply for the display 2 can be connected via a display connector (not shown). The display connector also receives control data for the display.

As mentioned above, as an alternative to the described arrangement, the transducers may support the display itself. In any event, they should be placed or mechanically coupled in such a way that they respond only to the component of a force which is perpendicular to the sensitive surface 1 (glass or display). The perpendicular component of a force applied to the sensitive surface 1 will be transmitted to the transducers T_1-T_4 in proportions determined by the point of application of the force. For a perfectly rigid structure, these proportions would be independent of the magnitude of the force. In practice, however, they will depend on the linearities of the compliances of the various structural components. In the present application it is relatively easy to maintain the necessary linearity over the expected range of forces.

For the illustrated example of a rectangular sensitive surface 1, it is convenient to determine the X and Y coordinates of the point of application of a force. Taking one of the transducers T_4 as the origin, (0,0), the other transducers are sited at positions T_1(0,Yo), T_3(Xo,0) and T_2(Xo,Yo). A force applied at position (X,Y) will be distributed in the ratio (XoYo+XY−XoY−XYo): (XoY-XY): (XYo-XY): (XY) respectively, and will produce outputs from the transducers in the same ratio assuming that the sensitivities of the transducers are similar. If necessary, variation in the sensitivities of the transducers can be compensated for electronically.

If the outputs from adjacent transducers are converted to voltages and are added together, the four voltages obtained will be in the ratio (XoYo-XYo): XYo: (XoYo−XoY): XoY. These correspond to the left hand, right hand, bottom and top edges of the rectangular surface respectively, and give ratios of voltages for opposite edges of (Xo−X): X and (Yo−Y): Y. It can be seen that the X and Y coordinates may be obtained from these ratios by suitable processing which produces outputs in the form of binary numbers.

Figure 2 illustrates a circuit suitable for one method of processing the voltages, as follows.

For each pair of opposite edges, the voltage corresponding to one edge is inverted and applied to one end of a chain of resistors. The voltage corresponding to the opposite edge is applied to the other end of the resistor chain. Each of the remaining nodes of the resistor chain is connected to the input of a voltage comparator. The comparator outputs will constitute a binary number corresponding to the x or y coordinates of the applied force. The two binary numbers obtained in this way can be encoded into any convenient form by additional digital circuits. A suitable strobe can be generated by applying the sum of the voltages corresponding to two opposite edges to a voltage comparator.

Owing to the capacitive nature of the transducers they should be connected to circuitry which has an extremely low level of leakage current. The first stage of this circuitry could consist of a voltage follower with a low leakage f.e.t. input. This arrangement on its own may be subject to long term drift and so should preferably incorporate auto-zero circuitry. In the embodiment to be described this consists of a suitably high resistance R_1-R_4 (10MΩ) connected in parallel with each transducer to restore its voltage to zero under quiescent conditions. The effects of this resistance on the transducer output can be minimised by incorporating an electronic bilateral switch in series with each restoring resistance.

Referring to Fig.2, the outputs of the four

corner transducers, T_1-T_4, mounted on the surface 1 are buffered by respective voltage followers, IC2a-d. The outputs of the voltage followers are applied to nodes of a resistor network, R5-R16 in such a way as to produce five signals corresponding respectively to the sums of adjacent transducer outputs and to the sum of all four transducer outputs. The signals corresponding to the top pair T_1,T_2 and to the left hand pair T_1,T_4 of transducers are inverted respectively by IC3a and IC3b, and the signal corresponding to all four transducers is inverted by IC3c. The output of IC3c is offset by a potential divider, R18-R20, and proportions thereof are applied to voltage comparators IC3d and IC4d, the latter being provided with hysteresis by R21.

Comparator IC3d provides an output which controls four bilateral switches IC1a-d, to cause the transducer output to be zeroed during the periods between applications of pressure by shunting them with resistors R1-R4. Under quiescent conditions the switch is closed. When the total force applied exceeds a preset level determined by the voltage comparator IC3d the switch is opened. For as long as the output remains above the threshold level, the output error will be solely dependent on parasitic leakages which can be kept extremely low by the use of circuitry employing field effect transistors (f.e.t.'s) in the input stages.

When the output falls below the threshold level, the restoring resistance is switched in and any accumulated error is eliminated. In order for this arrangement to function correctly, it is important that the time constant of the transducers and their restoring resistors is large compared with the risetime of the applied force, but small compared to the time between successive applications of force. A time constant of 100ms is appropriate in the present application.

IC4d provides an output which clocks an output register IC9 at the instant that a predetermined pressure has been reached. The input voltage for the comparator IC4d depends on the sum of the voltages from transducers T_1 to T_4. The resistor chains R25-R28 and R29-R37 drive voltage comparators IC4a-c and IC5a-d, IC6a-d which produce digital signals consisting of eleven bits of data corresponding to the x,y position of an applied force. These signals are decoded to six bits by IC7 and IC8 in such a way that indecision present in any one comparator will only affect one bit of the decoded output. This is to prevent spurious codes being generated if a force is applied at the boundary between the "virtual" keys on the sensitive surface 1. In such a case, the only possible output codes are those corresponding to the "keys" adjacent to the point of application of the force. The code is clocked into register IC9 under the influence of clock pulse from IC4d.

It will be appreciated that the arrangement described, in addition to being sensitive to externally applied forces, will also be sensitive to the effects of acceleration and gravitational fields by virtue of the mass of the sensitive surface 1. These effects are accommodated in the illustrated processing circuitry.

As regards acceleration, the only significant effect is that of vibration, which will introduce a.c. components into the transducer outputs. The illustrated circuitry includes strobe generating circuitry to render it insensitive to vibration by discriminating against short lived transducer outputs. A strobe pulse is only produced after a sustained output voltage of, say, 100 mS duration. Thus the output of IC4d is processed by IC10a-c to produce a delayed strobe pulse for external data transfer. The purpose of this delay of approximately 100mS is to prevent any vibration induced transducer outputs registering as a "key" depression.

The effect of gravity on the sensitive surface could be significant if its orientation is subject to change. The effect could appear as the equivalent of a permanent applied pressure. This effect can be eliminated by use of the fifth transducer T_5 behind the centre of the display 2 mechanically coupled to the weight 4. The output of the fifth transducer T_5 is applied to the non inverting input of IC3c where it is subtracted from the summed outputs of the other four transducers after appropriate weighting. The result is that the system is insensitive to changes in orientation.

One alternative method of implementing the necessary processing is as follows. The voltages corresponding to two opposite edges are added and applied to a voltage comparator. At the instant that a predetermined voltage is reached, the voltages corresponding to the right hand and top edges are input to an analogue to digital conversion system. The two binary numbers obtained correspond to the x and y coordinates of the applied force. These binary numbers can be encoded into any convenient form by additional digital circuits, or they may be input directly to a microprocessor system.

Other arrangements of the transducers and surface are possible. For example, the sensitive surface may be rigidly attached to the transducers, with these preferably located in a plane containing the points of contact on the surface. This is in order to render the transducer outputs independent of lateral forces applied to the sensitive surface.

If it is impracticable to site the transducers in such a position, or if it is more convenient to place the transducers in a different plane (e.g. on a printed circuit board behind the display) then forces may be transmitted to the transducers via linkage structures, and the sensitive surface may be constrained laterally by a means which is free from frictional forces perpendicular to the surface. Flexible straps in

the plane of the surface are suitable for this purpose. The lateral compliance of the linkage structures should be high enough to allow any residual lateral displacement of the sensitive surface without affecting the perpendicular components of forces at the transducers.

To avoid possible damage to the transducers by overstressing, the forces at the transducers should be limited by a stress relief mechanism. This could consist of perpendicular compliance in either the linkage to or support of the transducers or their supporting structure.

One such arrangement is shown in Figures 4 to 6. Here, the transducers T_1'- T_5' (T_1', T_2' are not shown) are placed on a printed circuit board (PCB) 7. They are coupled to the surface 1' by linkage structures 8 with stress relief mechanisms 9. The display 2' is carried by supports 10 on the PCB 7, the supports having buffers 11 below the surface 1'.

Figure 5 shows details of the linkage structure 8 and relief mechanism 9. The structure 8 is a piston 16/cylinder 17 arrangement, the piston 16 having a tapered end 12 disposed in an aperture 14 of the surface 1' and the cylinder 17 having a tapered end 13 disposed in an aperture 15 of the PCB 7. The transducer T4' is attached to the underside of the PCB, e.g. by soldering, and is connected to the PCB by wire 18. A spring 19 between the piston 16 and cylinder 17 provides stress relief. Flexible straps 20 provide lateral constraint for the surface.

An alternative linkage structure is partially illustrated in Figure 6. Here, a solid rod 21 is connected between the transducer and surface 1', the upper tapered end 22 of the rod being shown in Figure 6, received by aperture 14' in the surface 1'.

A phosphor bronze strip 23 having a preformed kink 24 serves the function of the straps 20 and provides stress relief. The strip 23 is riveted to the surface 1' with rivet 25.

Preferably the transducers used should be sensitive enough to avoid the necessity of a high level of amplification which could be unduly susceptible to noise pickup from sources of electromagnetic or electrostatic interference. In preferred embodiments of the invention, it will be appreciated that the transducers used should not be subject to drift, ageing, temperature effects or wear and should be self aligning and self adjusting in order to eliminate the effects of mechanical distortion of the sensitive surface or its supporting structure which could be introduced by environmental changes, the effect of vibration or stress relaxation in formed or moulded components. In addition, the cost of the transducers should be low since a minimum of three is required for any two dimensional system and five are required for the above-mentioned system.

The transducers used in an embodiment of the present invention consist of piezoelectric elements normally used for the generation of sound energy and incorporated in devices such as electronic calculators and watches.

As described above there is provided a pressure sensitive apparatus providing a keyboard which operates in accordance with a principle which provides for low cost, low complexity, extreme ruggedness, low power consumption and the ability to use any rigid surface of any shape or material as the sensitive surface. Also it is possible to resolve lateral forces as an additional input device, for example, for the implementation of shift or control functions on a conventional keyboard.

The circuitry for the above described arrangement may be packaged in a semi-custom integrated circuit. Hence, it may be commercially viable for portable computers to incorporate a touch screen.

In the above described embodiment, use of the device with a display has been discussed. Among the types of display which are applicable are LCD, CRT, electroluminescent, vacuum flourescent or plasma type displays. While use with a display is an important application, there are other applications where a display is not required. For example, in dirty or wet environments or where there is a risk of vandalisation, the device provides a rugged, completely sealed keyboard with virtually no moving parts. Keys of any shape or size could be marked directly on the surface which could be opaque or translucent with back illumination.

In another case, since any suitable solid object could be used as the surface or keyboard, the device could be used in security systems where code entry could be accomplished by touching known points on an object in sequence.

In another application, the display may be replaced by an interchangeable card with keys marked on it. This could be of possible use as a multilingual, or multifunctional keyboard.

CLAIMS

1. A pressure sensitive device comprising a member coupled to a plurality of transducers arranged to sense pressure applied to the member and disposed in spaced apart relationship such that when pressure is applied to the member at any one of a plurality of locations on the member and spaced from all the transducers, the pressure sensed by each transducer is dependent on the location at which said pressure is applied to the member, each transducer being capable of outputting a signal in dependence on the pressure sensed thereby.

2. A device as claimed in claim 1, in which said transducers are positioned in a peripheral zone of the member, the locations including locations occupying a central zone of the member.

3. A device as claimed in claim 2, in which

the member is rectangular, there being transducers positioned respectively at corners of the member.

4. A location sensing apparatus having a device as claimed in claim 1, 2 or 3 and means for processing said signals to provide signals representing coordinates of the location at which said pressure is applied.

5. An apparatus as claimed in claim 4, including a device according to claim 3, in which the processing means comprises:

means for combining the signals output from each set of two adjacent transducers to provide signals associated with respective edges of the member; and

means for comparing weighted representations of signals associated with opposite edges with a reference signal to provide said signals representing coordinates.

6. An apparatus as claimed in claim 5, which comprises:

means for inverting the signal associated with one edge of the member, and for applying the inverted signal to one node of a chain of resistive elements;

means for applying the signal associated with the opposite edge of the member to another node of the chain of resistive elements;

comparators for comparing signals at nodes intermediate the one and other nodes with a reference signal, the outputs of said comparators providing said signals representing coordinates.

7. A pressure sensitive device substantially as hereinbefore described with reference to, and as shown in, Figures 1 and 2 of the accompanying drawings.

8. A location sensing apparatus substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd, Dd 8817356, 1987.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.